

***The best approach for Outgassing and OoB issue
by EUV Top Coat
(OBPL: Outgassing and Out of Band Protection Layer).***

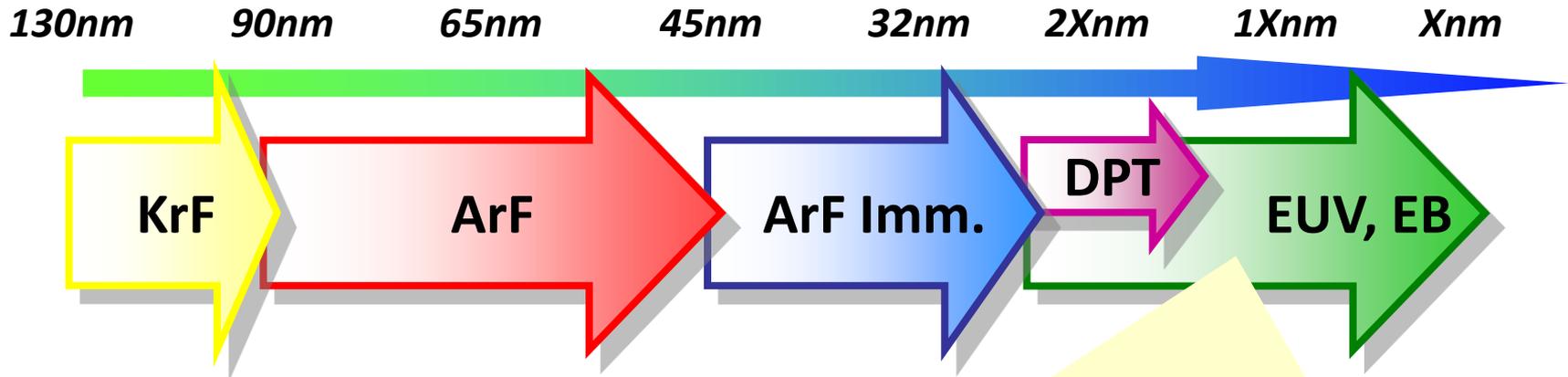
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Nissan Chemical Industries, LTD

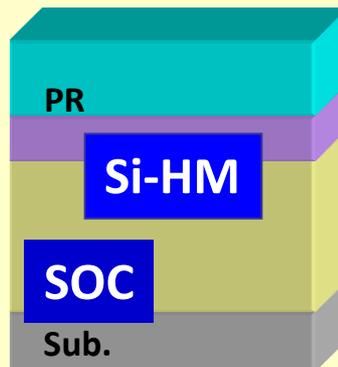
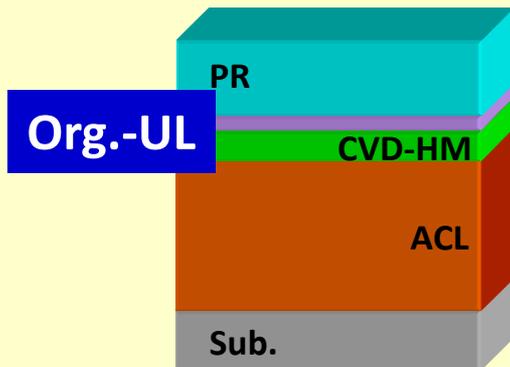
- 1. Introduction**
- 2. Outgassing barrier**
- 3. OoB study**
- 4. Lithography performance**
- 5. Conclusion**

Outline

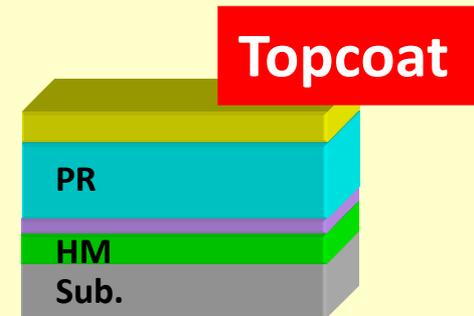
Lithography Technology



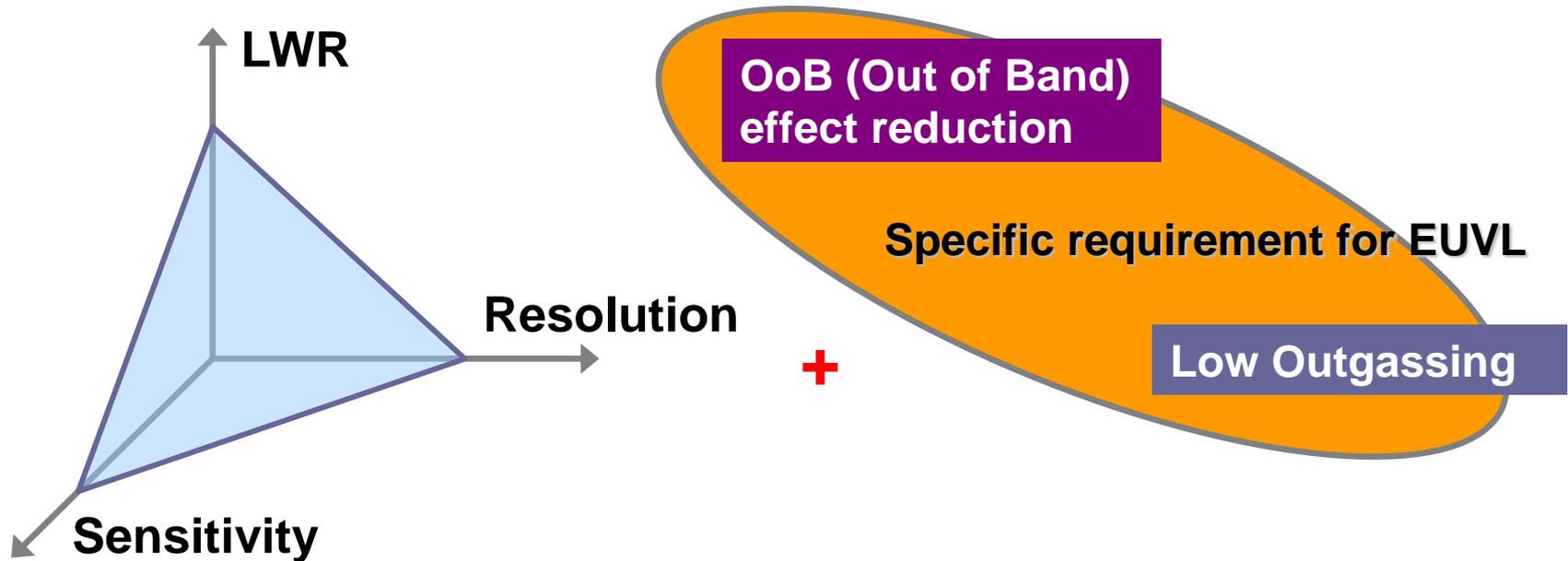
Nissan Chemical's activity for EUVL



Today's talk



Introduction



Smaller RLS trade-off is required for resist development.

Additionally, OoB resistance and low outgassing is also required for EUV resist.

Outgassing

- Using Pellicle
- Frequent cleaning
- **Optimization of Resist Chemistry & Formulation**

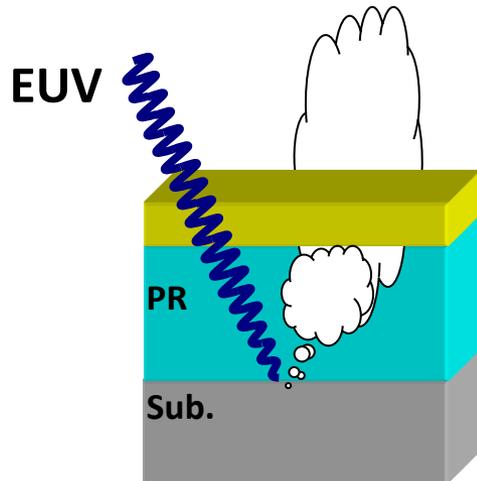
Out of Band (Mixing DUV light)

- Using Optical filter (Membrane)
- **Optimization of Resist Chemistry & Formulation**

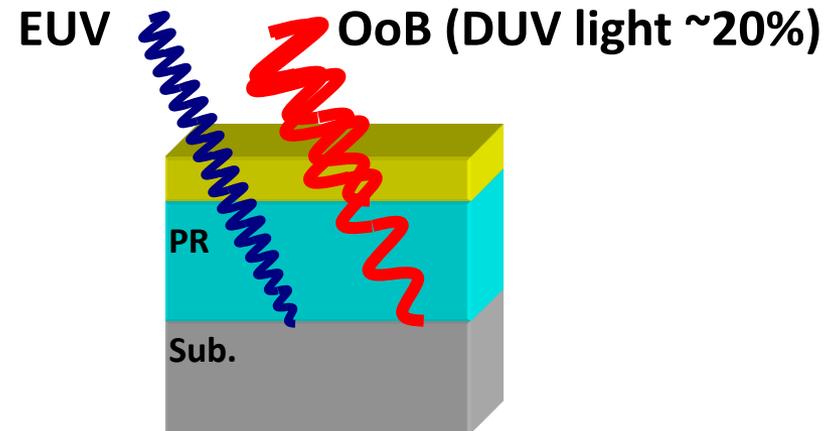
**Resist optimization is the key direction for
Outgassing and OoB issue, now.**

OBPL

Outgassing & Out-of-Band Protection Layer

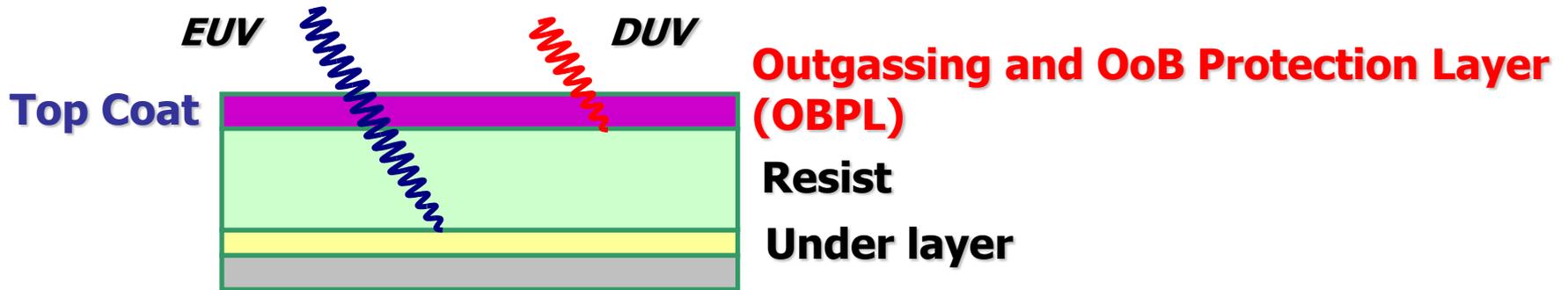


Outgassing barrier



Out-of-Band filter

Concept of Top Coat material



Characteristic of OBPL :

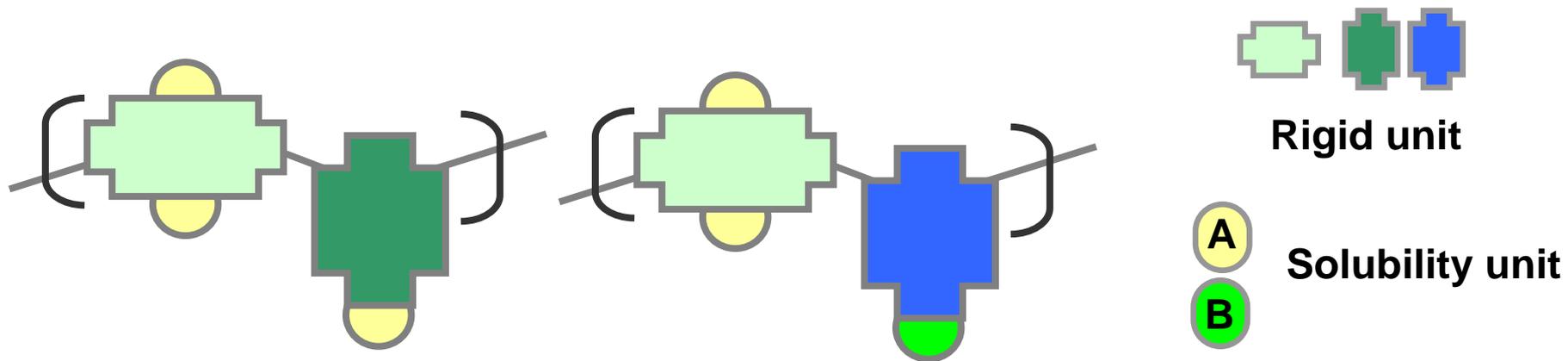
- 1. Low transmittance for OoB light**
- 2. High transmittance for EUV light**
- 3. Prevention of outgassing from resist**

} **Specific property for EUVL**

- 4. No mixing with resist film**
- 5. Removable by development and rinse process**

} **Common property with TARC and imm. TC**

Material design Concept



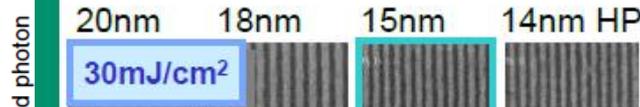
- **Ridged unit** : high outgassing barrier property and DUV abs.
- **Solubility unit A**: Developable unit into TMAH/DIW (For PTI)
- **Solubility unit B**: Solubility unit for OBPL Solvent (org.Solvent) and NBA (For NTI)

Outgassing

PSN in EUVL

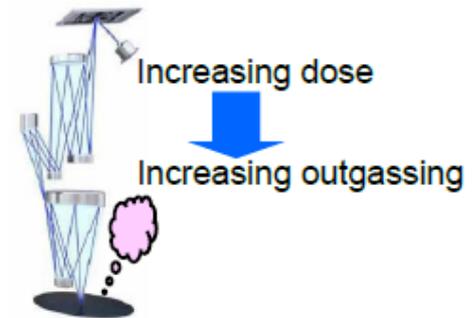
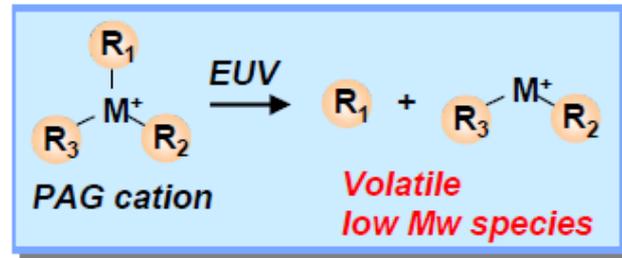
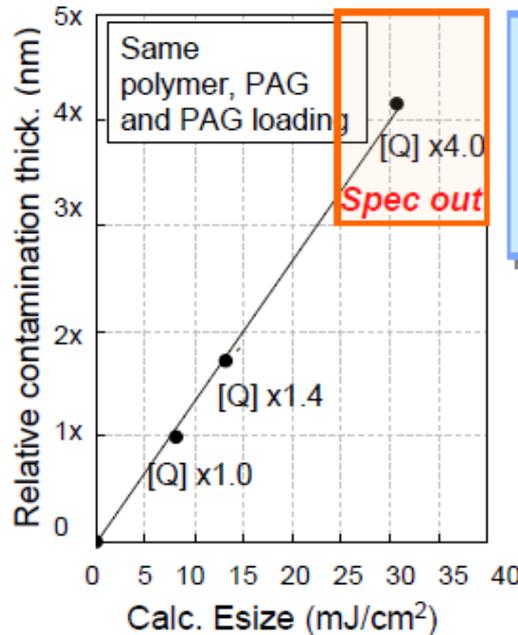
| | | |
|-----------|--|-------------|
| | Required photon cts. for resolution (pinching cts. < 10) | |
| HP of L/S | EUV (LBNL MET) | EB (50 keV) |
| 30 nm | FUJIFILM Corporation | |
| 20 nm | | |
| 15 nm | | |
| 11 nm | | |

Resolution – sensitivity tradeoff



Res. ⇒ **Large** photon cts. is preferable

Resolution – outgassing tradeoff



Slow Esize. for high res (1x nm). caused outgassing

Below Hp15 Generation.

More than 2000 photon will be required to get

The enough Resolution and imaging quality.

→ High dose (>30mJ) will be exposed to PR.

→→ **Outgass must be higher and higher.**

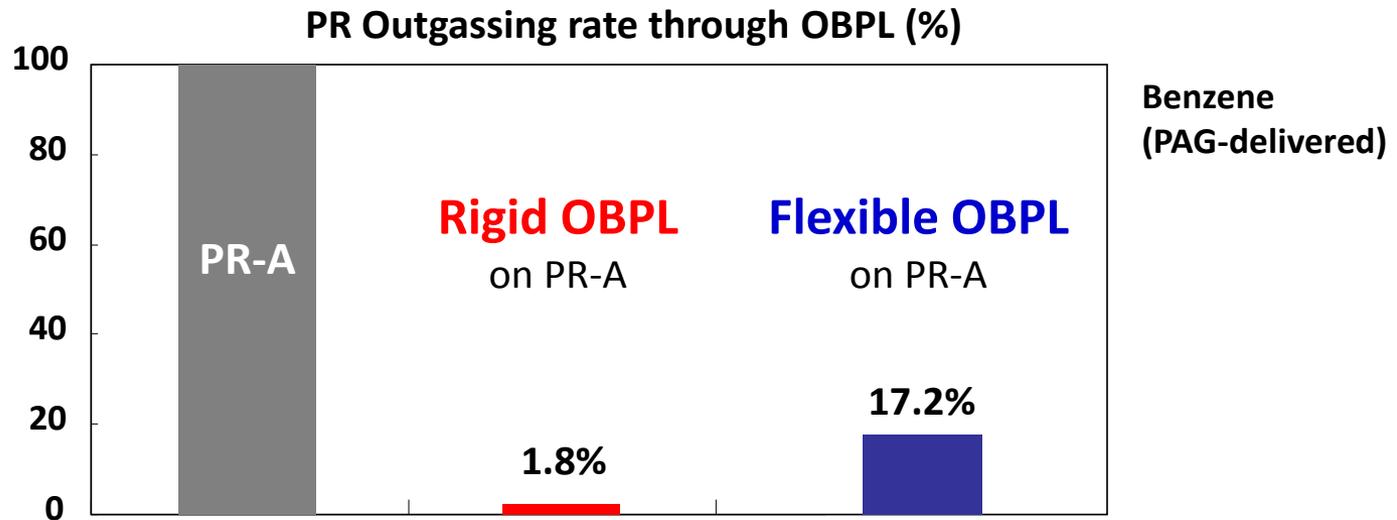
Because of trade off between Res. & Outgass.

EUV-TC will be required for Hp15 and beyond

Previous study by RGA

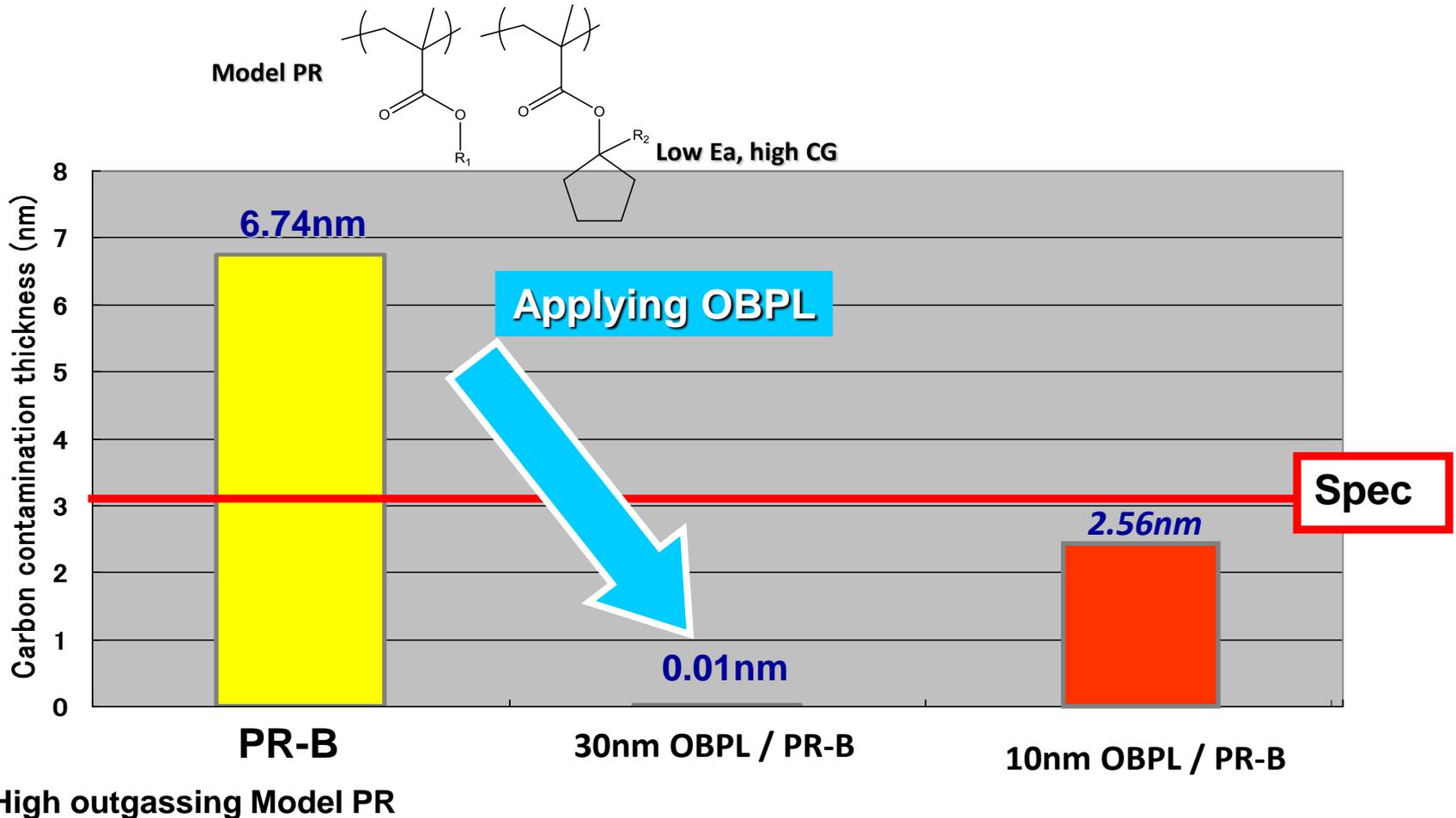


| | OBPL-1 | OBPL-2 |
|-----------------------------------|-----------------------|--------------------------|
| Polymer platform | Rigid type | Flexible type |
| Film density (g/cm ³) | 1.21 | 1.15 |



**Chemistry dependency for outgass barrier was confirmed,
But applying OBPL could reduce the outgassing significantly.**

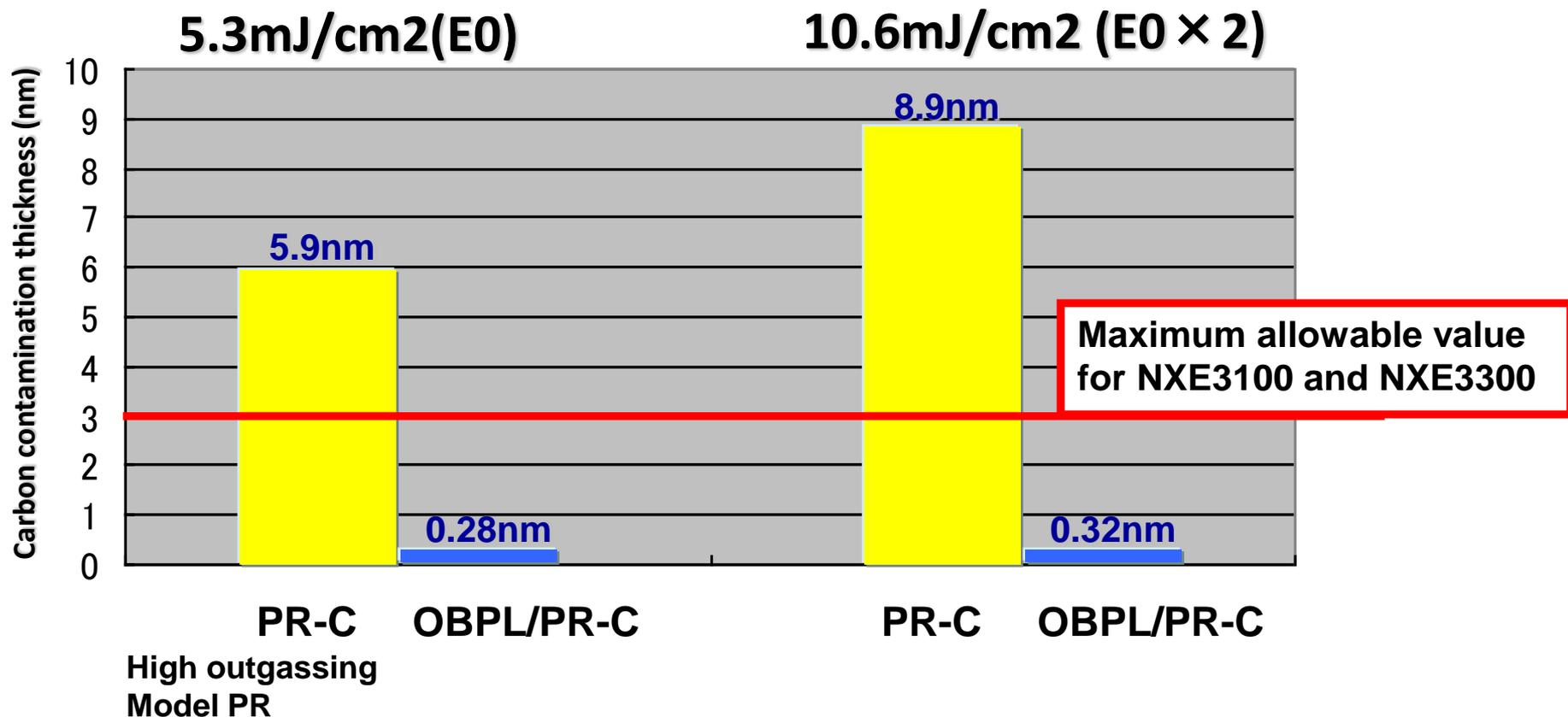
Outgassing barrier test



OBPL could reduce the CG dramatically.

Even 10nm FTK OBPL could make spec in high outgassing PR.

Dose split



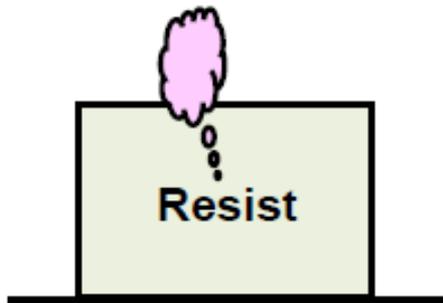
OBPL could barrier the outgassing under the very high dose condition!!

NTI compatibility

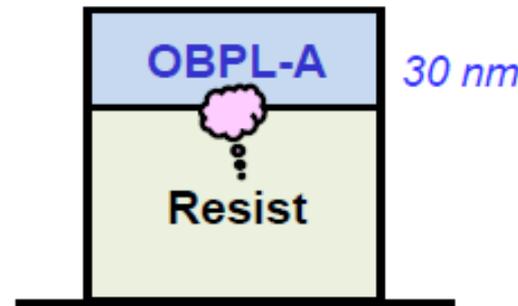
Cleanable contamination growth



7.39 nm



< 0.1 nm



Topcoat drastically reduced outgassing

SPIE Advanced Lithography 2013 (February 25, 2013)

FUJIFILM

SPIE 2013, H. Tubaki, et al.

Summary

| | | |
|----------------|----------------------------|--|
| Site | Site-A Site-B Site-C |  |
| PR | PTD type NTD type |  |
| Dose condition | E0 E0 × 2 |  |
| OBPL FTK | 30nm 10nm |  |

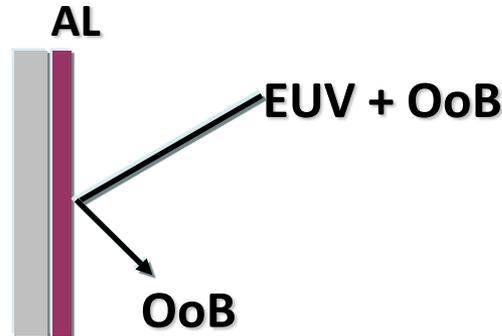
PR: High outgassing Model PR

OoB study



DC2 AL

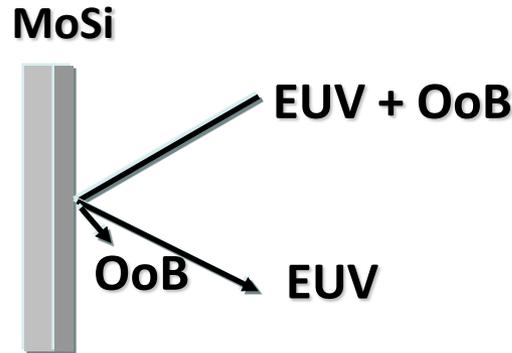
OoB included



E₀ measurment

DC2 ML

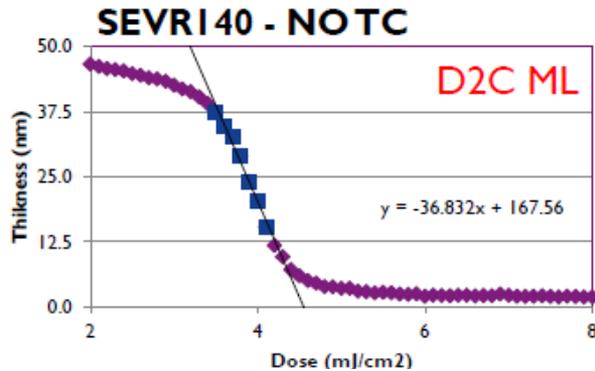
EUV only



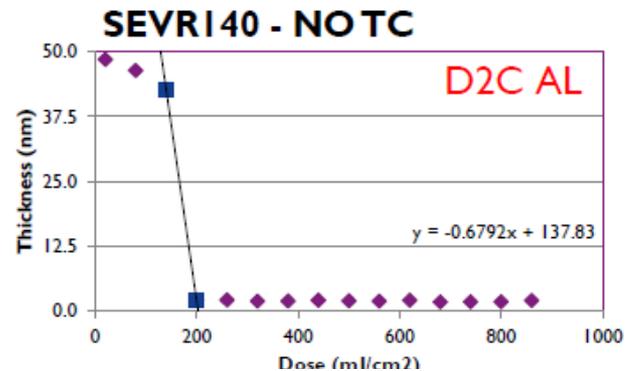
E₀' measurment

$$\text{OoB sensitivity} = \frac{E_{0'}}{E_0} \times 100 (\%)$$

Study of OoB effect

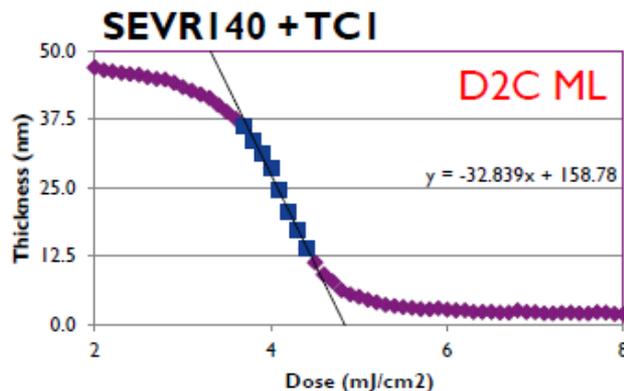


$$E_0 = 4.54 \text{ mJ/cm}^2$$

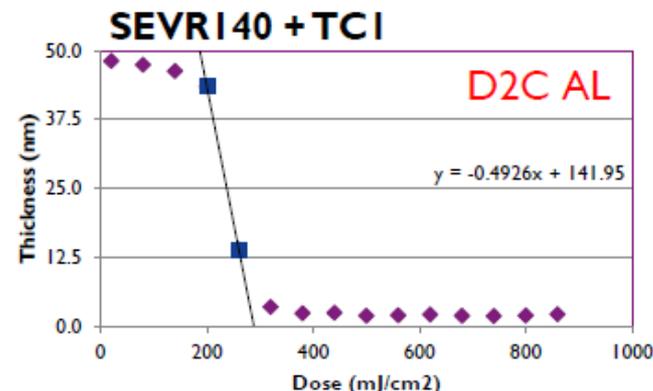


$$E_0 = 202.92 \text{ mJ/cm}^2$$

OoB = 2.25%



$$E_0 = 4.96 \text{ mJ/cm}^2$$



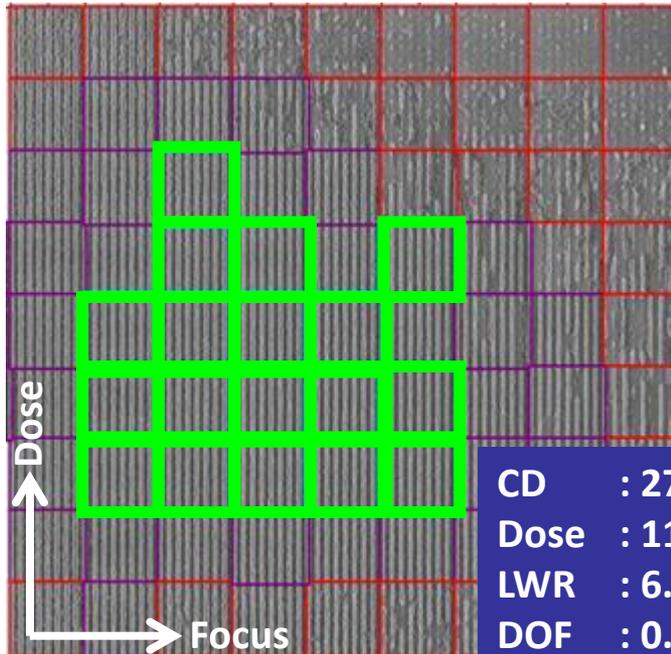
$$E_0 = 286.07 \text{ mJ/cm}^2$$

OoB = 1.73%

20% OoB sensitivity loss by OBPL was confirmed.

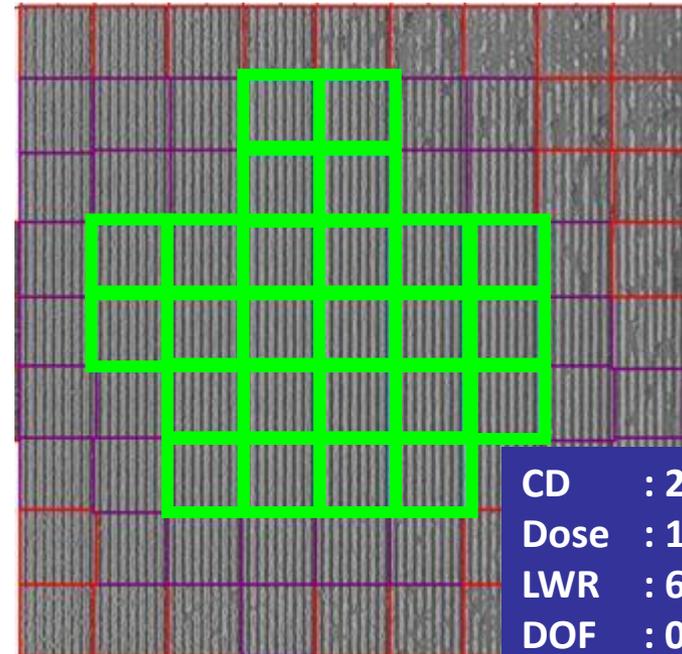
Lithographic performance with NXE:3100

without OBPL



CD : 27.7nm
 Dose : 11.2mJ/cm²
 LWR : 6.4nm
 DOF : 0.20um

with OBPL



CD : 27.4nm
 Dose : 11.5mJ/cm²
 LWR : 6.6nm
 DOF : 0.22um

**OoB reducing by OBPL could help to get wider process window
 Without pattern degradation.**

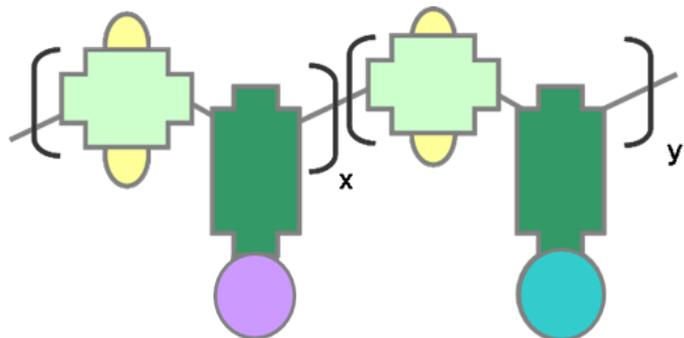
Lithography

Concept: Universal TC for PR and process

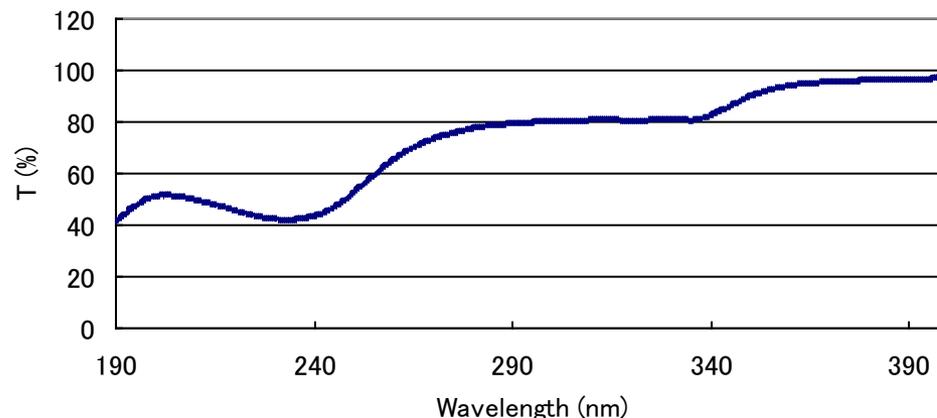
| | |
|-----------------------------|---|
| Polymer platform | Rigid type |
| OoB absorption |  |
| Outgassing barrier |  |
| Litho performance |  |
| Resist compatibility | Universal |
| Applicable for Dev. process | PTD & NTD |

Candidate material

Material design



DUV transmittance of 30nm OBPL



Sample property (NCX2088)

| Sample name | Polymer platform | R unit | Outgassing qualification | | Transmittance (30nm) | |
|-------------|------------------|------------------|--------------------------|--------------|----------------------|-----------|
| | | Type | Qualification | Barrier test | 13.5nm | 190-240nm |
| NCX2088 | Rigid | High hydrophilic | Pass | | 81% | 43% |

High DUV abs. and good outgass barrier property

Methacrylate type PR

Tester / location: Sematech (AMET)



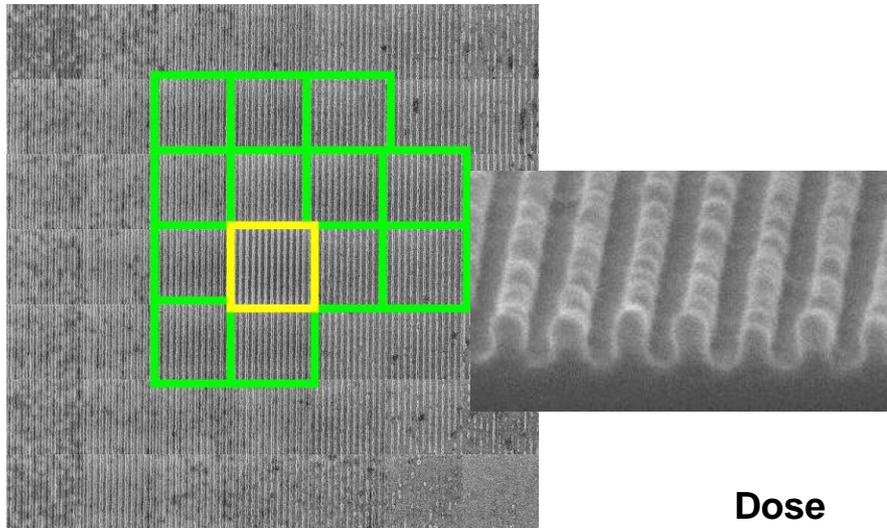
Best shot



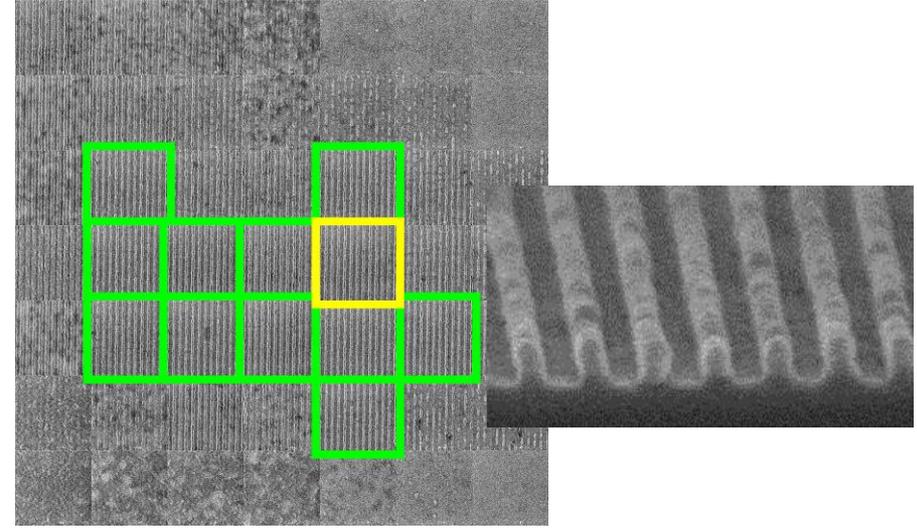
Pattern standing

Focus

Resist-C



NCX2088 / Resist-C



Dose

| | |
|----------------------------|------|
| CD (nm) | 27.3 |
| Dose (mJ/cm ²) | 11.5 |
| LWR (nm) | 4.3 |
| Max EL (%) | 13.0 |
| Max DOF (um) | 0.20 |

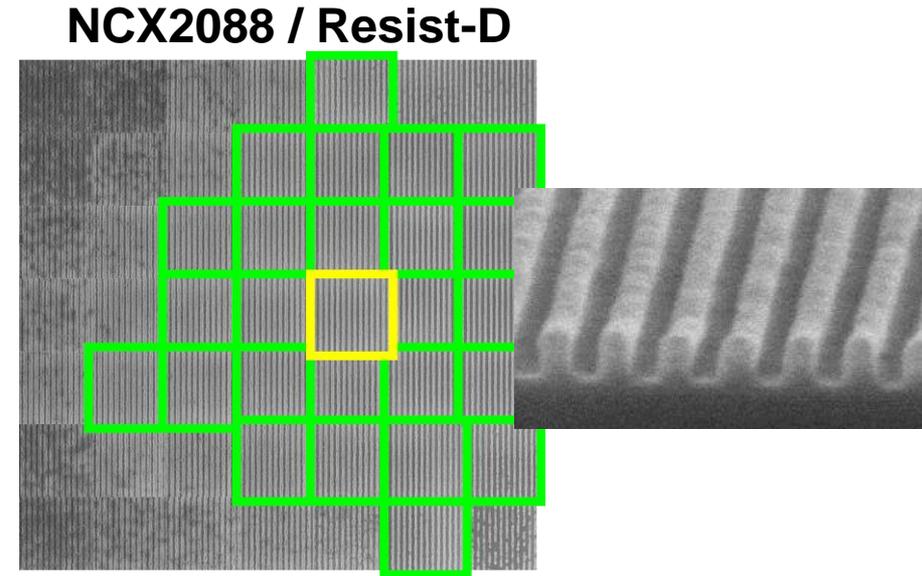
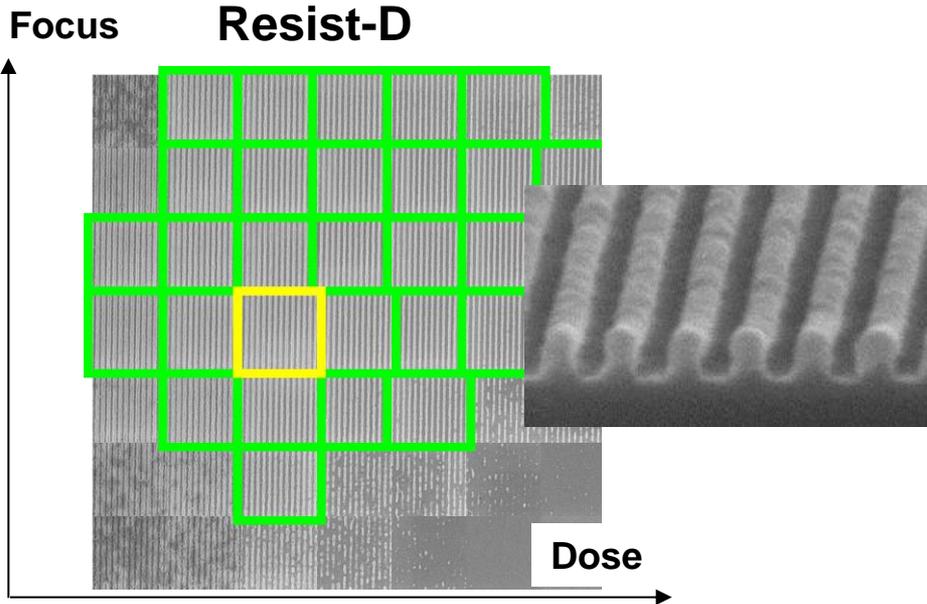
| | |
|---------|------|
| CD | 28.1 |
| Dose | 14.0 |
| LWR | 4.5 |
| Max EL | 10.7 |
| Max DOF | 0.20 |

Applying OBPL keep good process margin and LWR.

HS/Methacrylate hybrid type

Tester / location: Sematech (AMET)

Best shot
 Pattern standing



| | |
|---------------------------|--------|
| CD (nm) | 26.1 |
| Dose(mJ/cm ²) | 24.0 |
| LWR (nm) | 4.0 |
| Max EL (%) | > 29.2 |
| Max DOF (um) | > 0.30 |

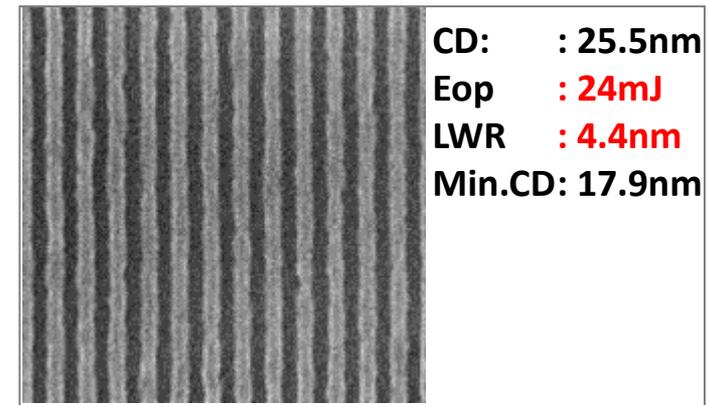
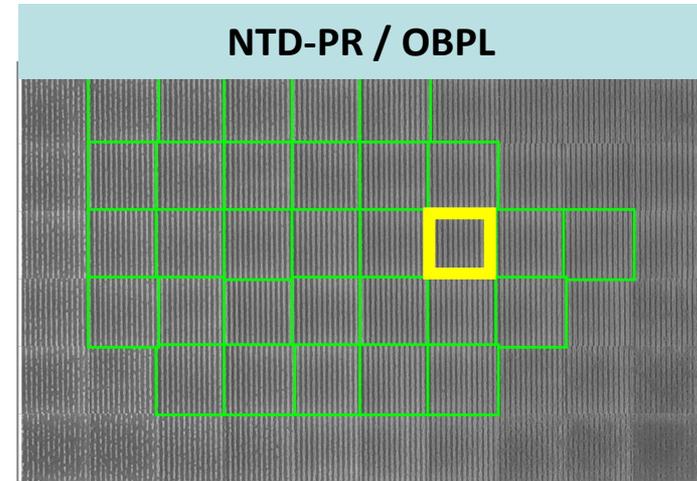
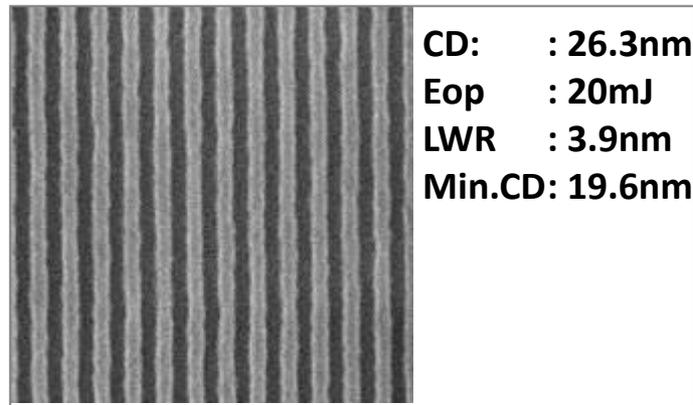
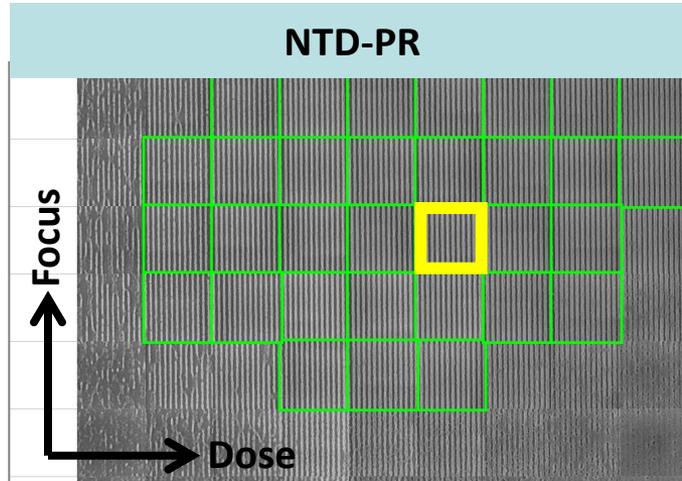
| | |
|---------|--------|
| CD | 25.7 |
| Dose | 27.0 |
| LWR | 4.1 |
| Max EL | > 18.5 |
| Max DOF | > 0.30 |

Applying OBPL keep good process margin and LWR.

EUV-NTI



Tool : AMET
UL : NCX1338A (30nm)
PR : NTD-PR
OBPL : Similar to 2081A(30nm)
Target : hp 26nm



Applying OBPL keep good process margin and LWR in NTD.

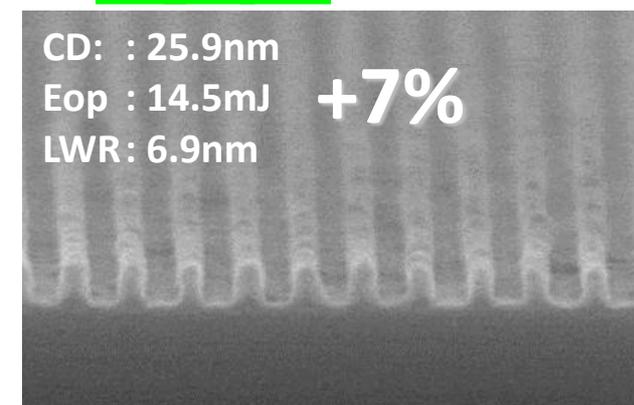
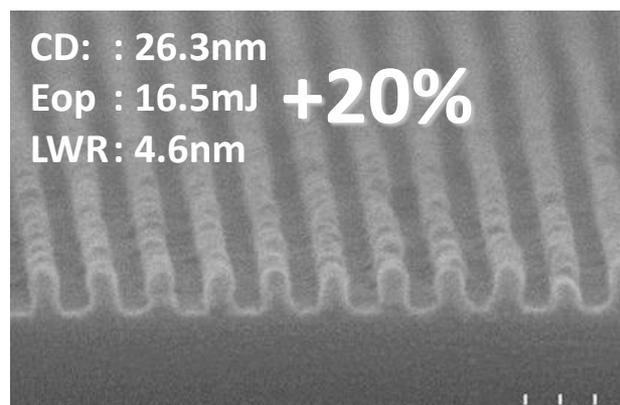
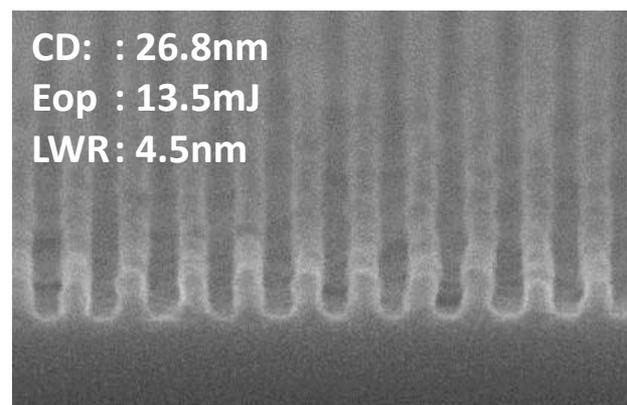
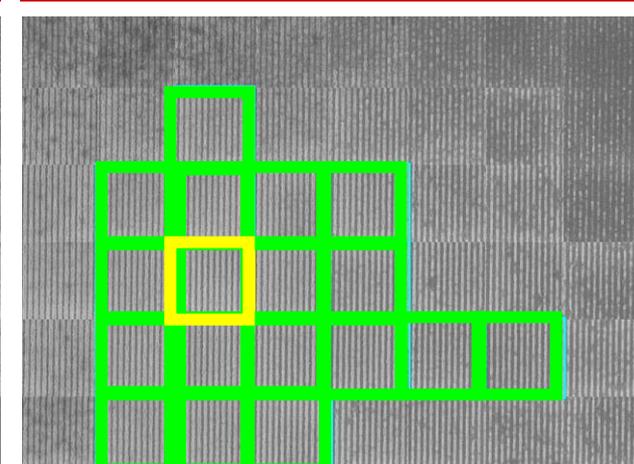
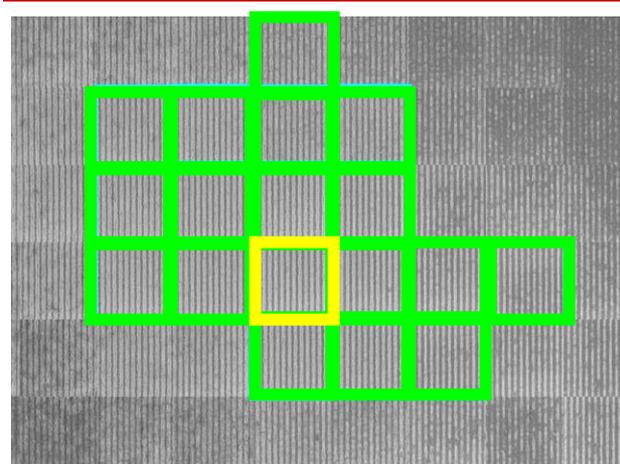
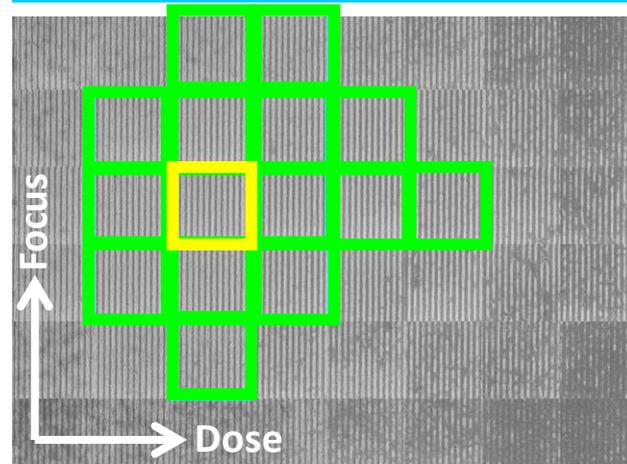
NISSAN CHEMICAL INDUSTRIES, LTD. Electronic Materials Research Laboratories.

Thickness Effect

w/o OBPL

with 30nm Rigid OBPL

with 10nm Rigid OBPL



Thin thickness OBPL got higher sensitivity than 30nm thickness.

Summary

Outgassing

Perfect barrier property was confirmed.
WS qualification of Staked (PR/OBPL),
SPEC-OUT PR could be SPEC-IN by OBPL!!

OBPL

Universality

PR kinds and Process

Methacrylate type PR(PTI)
PHS hybrid type PR (PTI)
NTI resist

OoB

High DUV abs. could prevent
OoB irradiation effect.

Conclusion

- Nissan Chemical has successfully developed **OBPL** for EUVL.
- OBPL has **PR outgassing barrier** property and **Out-of-Band filter** effect.
- Good PR universality and process compatibility were confirmed in OBPL process.

OBPL is the material for Outgass and OoB issue.

→OBPL is the material for expanding the room of the photo resist design for RLS improvement.

Good RLS property but very high outgassing PR can be applicable

Combine with OBPL!!

Acknowledgement



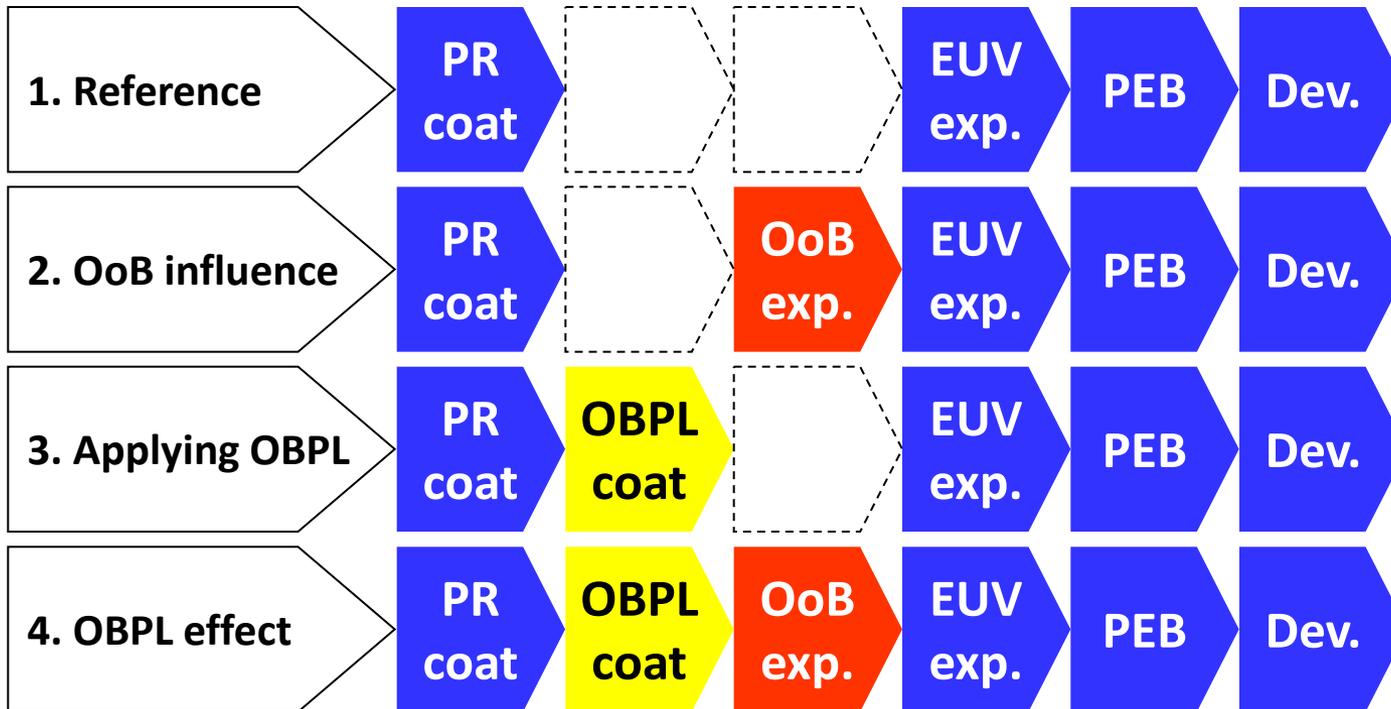
FUJIFILM

tok

Thank you for your kind attention.

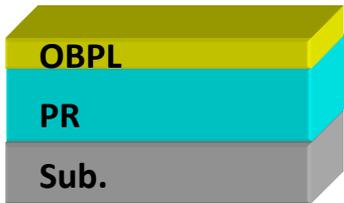
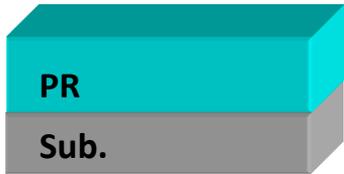
Investigation of OBPL effect

S.A. George *et al.*,
SPIE (2011)

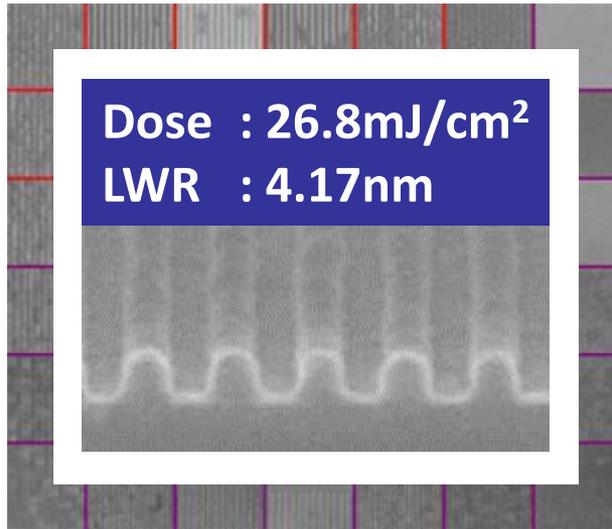


OoB exposure condition
 Wavelength: 160~300nm (broad band)
 Dose: 5.0mJ/cm² (20% of EUV)

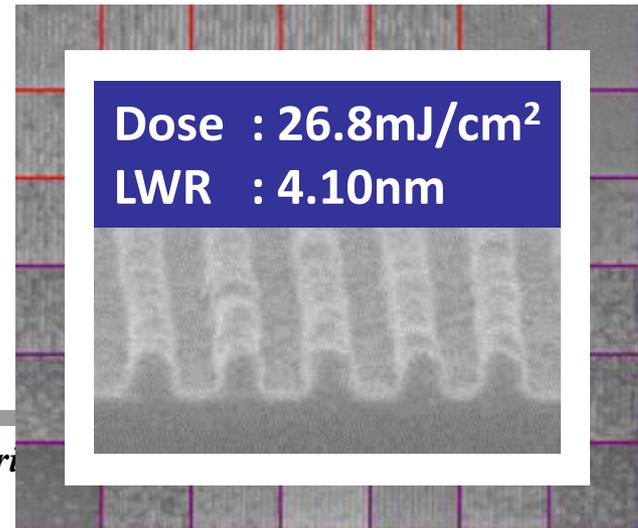
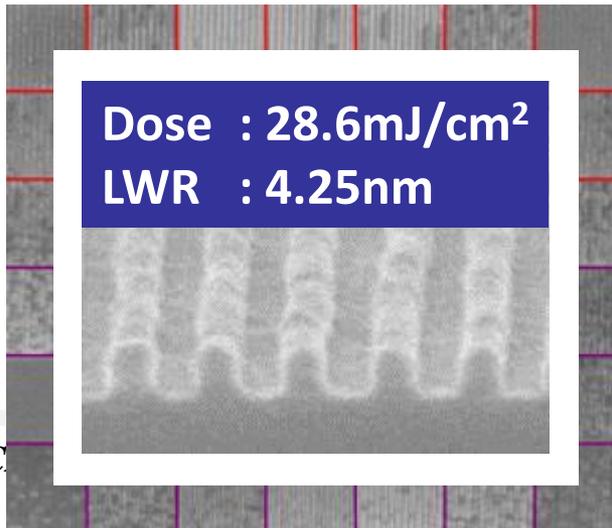
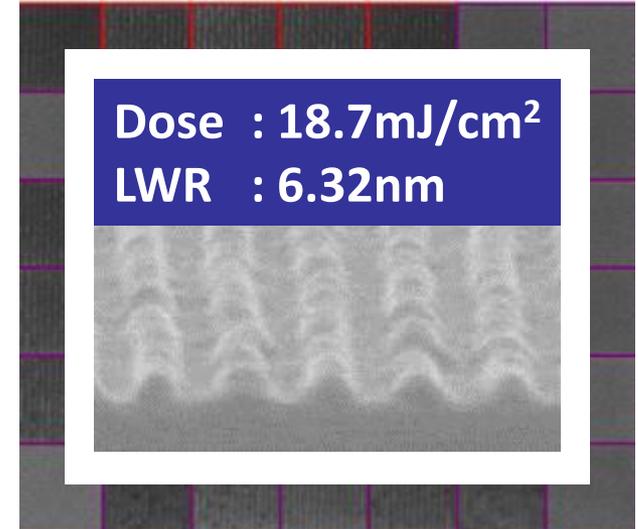
OBPL effect results



EUV

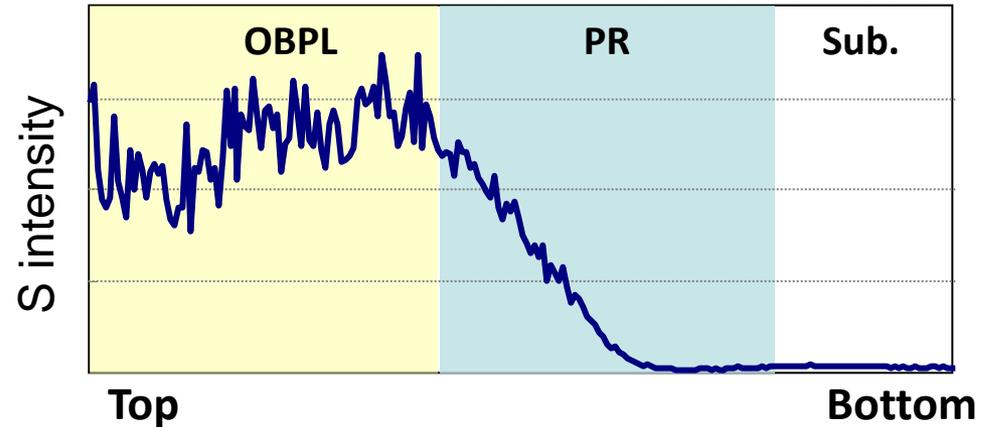
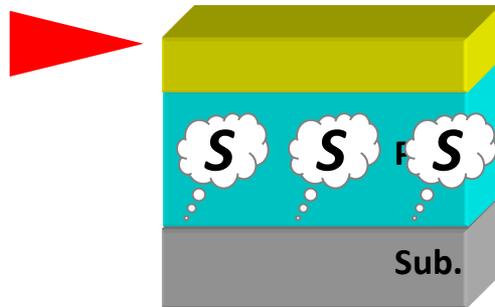


EUV + OoB

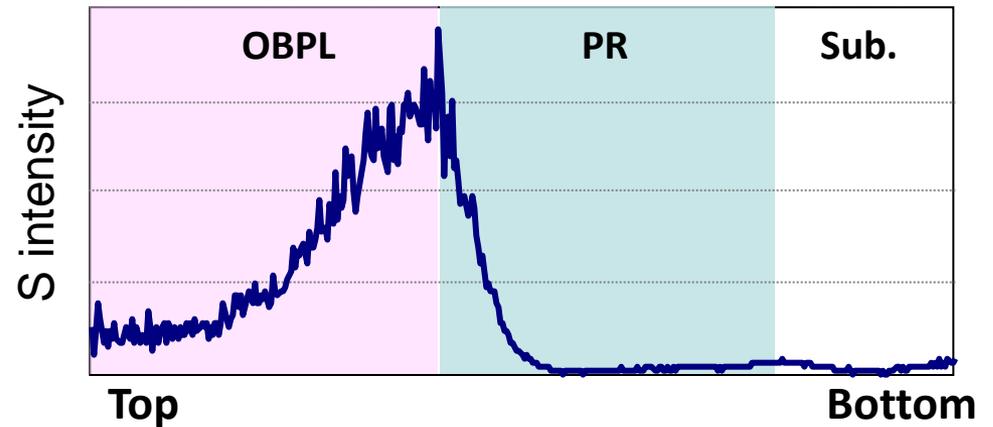
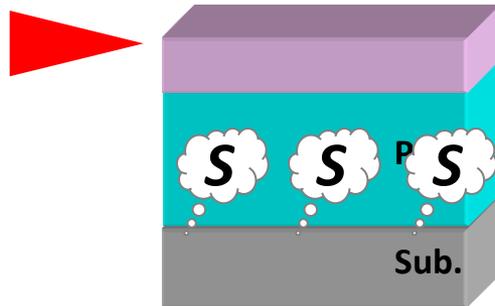


Variation concentration of Sulfur atom

Flexible OBPL



Rigid OBPL



Rigid OBPL blocks PR outgassing at interface.